Aligned Boron Nitride Nanotube Forests for Thermal Management

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Purpose:

An innovative approach to utilize aligned boron nitride nanotubes (BNNT) has been proposed in this effort as a thermal interface material between a heat source and heat sink in high power density components of interest for electric aircraft. BNNT is highly thermally conductive, with thermal conductivity even better than that of CNT (measured as BNNT - 350 W mK^{-1} versus 300 W mK^{-1} for CNT (both for outer tube diameters of 30–40 nm tube). Both BNNT and CNT are predicted to be in excess of 3000W m K^{-1} for 14 nm tube diameters). At the same time, BN is an electrical insulator with a volume resistivity of at least 10^{15-18} ohm cm and also is one of the best dielectric materials with the highest known dielectric strength of 2x 10^5 V/mm. This strength value is unaffected at temperatures up to 1000°C. While there has been considerable research on developing aligned CNT, similar research on growing aligned BNNT is nearly non-existent due to the more difficult chemistry with regards to the polar nature of the B-N bonding.

Background

There is a growing trend toward more electric aircraft to optimize energy efficiency. The future outlook calls for hybrid electric propulsion systems for large commercial aircraft, where electric motors driven by either power generated from turbines or energy storage systems will drive the fan. Thermal management becomes a major challenge for electric (or more electric) aircraft that require many high power density components, such as electric motors, power electronics, and high voltage transmission. For example, one of the major barriers for achieving high power density in electric motors is effective heat transfer to avoid increased temperature within electric coils and permanent magnets. Similarly, the temperature increase in power electronics limits their power density. Also as battery life is limited by temperature increase during rapid discharge cycles, clearly effective thermal management would increase battery life in electric aircraft. One approach for thermal management is to transfer the heat to a heat sink through a thermal interface material (TIM). Aligned carbon nanotube (CNT) forests are under development as TIM for thermal management in numerous applications such as batteries and power electronics because of their very high thermal conductivity. However carbon nanotubes are electrically conductive and have oxidative stability limited to below 500°C. For many applications where the heat sink is the primary structure itself or the heat sink is attached to the primary structure, it would be highly beneficial to have a thermal interface material that is thermally conductive, but electrically insulating. The proposed effort will develop such an interface by utilizing unique properties (combination of very high thermal conductivity and electrical resistivity) of boron nitride nanotubes (BNNT).

BNNT is much more difficult to synthesize than CNT and for this reason has not yet been pursued for TIM applications. NASA-GRC has demonstrated extensive morphology control of BNNT in the past and is ideally situated to pursue this research.